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<b>(21) International Application Number:</b> PCT/GB99/00585 <b>(22) International Filing Date:</b> 26 February 1999 (26.02.99)  <b>(30) Priority Data:</b> 9804885.3                      6 March 1998 (06.03.98)                      GB  <b>(71) Applicant (for all designated States except US):</b> MERCK SHARP & DOHME LIMITED [GB/GB]; Hertford Road, Hoddesdon, Hertfordshire EN11 9BU (GB).  <b>(72) Inventor; and</b> <b>(75) Inventor/Applicant (for US only):</b> BOYCE, Susan [GB/GB]; Terlings Park, Eastwick Road, Harlow, Essex CM20 2QR (GB).  <b>(74) Agent:</b> HORGAN, James; Merck & Co., Inc., European Patent Dept., Terlings Park, Eastwick Road, Harlow, Essex CM20 2QR (GB).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
<b>(54) Title:</b> COMBINATION OF A SELECTIVE NMDA NR2B ANTAGONIST AND AN OPIOID ANALGESIC  <b>(57) Abstract</b>  The present invention provides a combination of a selective NMDA NR2B antagonist and an opioid analgesic for use in the treatment or prevention of pain or nociception.		

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COMBINATION OF A SELECTIVE NMDA NR2B ANTAGONIST  
AND AN OPIOID ANALGESIC

This invention relates to the treatment or prevention of pain or  
5 nociception by the administration of a combination of a selective NMDA  
NR2B antagonist and an opioid analgesic.

Pain has been defined as the sensory experience perceived by nerve  
tissue distinct from sensations of touch, pressure, heat and cold. It is often  
described by sufferers by such terms as bright, dull, aching, pricking,  
10 cutting, burning, etc. This range of sensations, as well as the variation in  
perception of pain by different individuals, renders a precise definition of  
pain near impossible. Pain as suffering, however, is generally considered  
to include both the original sensation and the reaction to that sensation.  
Where pain is "caused" by the stimulation of nociceptive receptors and  
15 transmitted over intact neural pathways, this is termed nociceptive pain.  
Alternatively, pain may be caused by damage to neural structures, often  
manifesting itself as neural supersensitivity, and is classed as neuropathic  
pain.

The level of stimulation at which pain is perceived is referred to as  
20 the "pain threshold". Where the pain threshold is raised, for instance, by  
the administration of an analgesic drug, a greater intensity or more  
prolonged stimulus is required before pain is experienced. Analgesics are  
a class of pharmaceutical agent which, following administration to a  
patient in need of such treatment, relieve pain without loss of  
25 consciousness. This is in contrast to other pain-relieving drugs, for  
example, general anaesthetics which obtund pain by producing a hiatus in  
consciousness, or local anaesthetics which block transmission in  
peripheral nerve fibres thereby preventing pain.

NMDA (N-methyl-D-aspartate)-type glutamate receptors are  
30 believed to play a pivotal role in the transmission of excitatory signals  
from primary sensory neurones to the brain through the spinal cord  
(A. H. Dickenson (1990) Trends Pharmacol. Sci., 11, 307-309). NMDA

receptors mediate  $\text{Ca}^{2+}$  influx into neurones, and its receptor-gated channel activity is blocked by  $\text{Mg}^{2+}$  in a voltage-dependant manner. Subunits of the NMDA receptors are classified into two gene families, i.e., NR1 and NR2. A variety of compounds have been designed as antagonists  
5 targeting these subunits of the NMDA receptor for the treatment of neurodegenerative disorders, as well as acute and/or chronic pain and hyperalgesia. The NR2B subunit is predominantly expressed in the hippocampus (Ishii *et al.*, (1993), J. Biol. Chem. 268, 2836-2843).

NMDA antagonists such as ketamine, dextromethorphan and CPP  
10 are known to have analgesic properties in man. However, these agents also induce unacceptable side-effects including hallucinations, dysphoria and cognitive and motor disturbances (see Kristensen *et al.*, 1992, Pain, 51, 249ff; Price *et al.*, 1994, Pain, 59, 165ff and Max *et al.*, Clin. Neuropharmacol., 118, 360ff). In preclinical studies, dextromethorphan  
15 has been reported to potentiate the antinociceptive effects of NSAIDS and morphine (Price *et al.*, 1996, Pain, 68, 119-127; Mao *et al.*, 1996, Pain, 67, 361-368). However, since dextromethorphan can induce adverse effects at analgesic doses in man, it is not clear from these studies whether such combinations would still be dogged with unwanted side-effects.

20 One selective NMDA NR2B antagonist CP-101,606 is known to possess anti-nociceptive activity, see Taniguchi *et al.*, B. J. Pharmacol., 1997, 122, 809-812. Potent analgesic activity of this compound was shown in rat hyperalgesic and nociceptive tests at doses showing no behavioural abnormality.

25 There is, however, no general teaching in the art that all selective NMDA NR2B antagonists are useful as analgesics, nor that they have improved motor side-effect profile compared to NMDA/glycine antagonists. Evidence for this is, for the first time, provided herein.

Furthermore there is no suggestion in the art that selective NMDA  
30 NR2B antagonists could potentiate the effects of opioids, such as morphine, thus providing analgesia with suprisingly reduced side-effects,

such as motor-impairment. Thus the safety margin for the use of opioids, such as morphine, is surprisingly improved. There is no indication in the art relating to NMDA antagonists that the property of potentiating the action of morphine could be transferred to compounds selective for the NR2B subunit.

As the present specification surprisingly demonstrates that selective NMDA NR2B antagonists possess antinociceptive effects in rat models of inflammatory and neuropathic pain with a much improved side-effect window over non-competitive NMDA antagonists (ataxic/antinociceptive), when combined with an opioid, the combination is better tolerated than expected.

The opioid analgesics are a well-established class of analgesic agent. They are also sometimes referred to as opiates although this term should be reserved for chemical relatives of morphine. The term opioid is generally accepted to refer in a generic sense to all drugs, natural or synthetic, with morphine-like actions. The synthetic and semi-synthetic opioid analgesics are derivatives of five chemical classes of compound: phenanthrenes; phenylheptylamines; phenylpiperidines; morphinans; and benzomorphans. Pharmacologically these compounds have diverse activities, thus some are strong agonists at the opioid receptors (e.g. morphine); others are moderate to mild agonists (e.g. codeine); still others exhibit mixed agonist-antagonist activity (e.g. nalbuphine); and yet others are partial agonists (e.g. nalorphine). Whilst an opioid partial agonist such as nalorphine, (the N-alkyl analogue of morphine) will antagonise the analgesic effects of morphine, when given alone it can be a potent analgesic in its own right.

Of all of the opioid analgesics, morphine remains the most widely used and is a suitable archetype compound. Unfortunately, apart from its useful therapeutic properties, morphine also has a number of drawbacks including sedation, respiratory depression, decreased gastrointestinal motility (resulting in constipation) and, in some individuals, nausea and

vomiting may occur. Another characteristic is the development of tolerance and physical dependence which may limit the clinical use of such compounds. There is therefore a need to develop methods which enable the clinician to use lower doses of opioid analgesics such as morphine, thereby reducing the likelihood of adverse effects and development of tolerance and dependence, and thus avoiding the major problem of drug withdrawal associated with cessation of administration.

The present invention accordingly provides the use of a selective NMDA NR2B antagonist and an opioid analgesic for the manufacture of a medicament for the treatment or prevention of pain or nociception.

The present invention also provides a method for the treatment or prevention of pain or nociception, which method comprises administration to a patient in need of such treatment an amount of a selective NMDA NR2B antagonist and an amount of an opioid analgesic such that together they give effective pain relief.

In a further aspect of the present invention, there is provided a pharmaceutical composition comprising a selective NMDA NR2B antagonist and an opioid analgesic, together with at least one pharmaceutically acceptable carrier or excipient.

It will be appreciated that the selective NMDA NR2B antagonist and opioid analgesic may be present as a combined preparation for simultaneous, separate or sequential use for the treatment or prevention of pain. Such combined preparations may be, for example, in the form of a twin pack.

In a further or alternative aspect of the present invention, there is therefore provided a product comprising a selective NMDA NR2B antagonist and an opioid analgesic as a combined preparation for simultaneous, separate or sequential use in the treatment or prevention of pain or nociception.

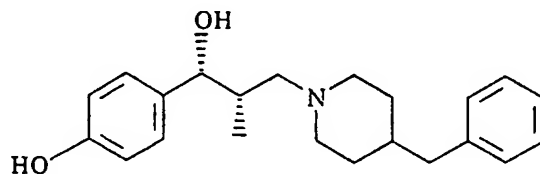
The compositions of the present invention are useful for the treatment of pain of any etiology, including acute and chronic pain and

any pain with an inflammatory component. Examples of acute pain include, in particular, post-operative pain, migraine, headache and trigeminal neuralgia. Examples of chronic pain include, in particular, pain associated with musculo-skeletal disorders such as rheumatoid arthritis, osteoarthritis, ankylosing spondylitis, sero-negative (non-rheumatoid) arthropathies, non-articular rheumatism and peri-articular disorders, and pain associated with cancer, peripheral neuropathy and post-herpetic neuralgia. Examples of pain with an inflammatory component (in addition to some of those described above) include rheumatic pain, dental pain and dysmenorrhoea.

The compositions of the present invention are especially useful for the treatment of pain where the use of an opioid analgesic is generally prescribed. By the use of a combination of a selective NMDA NR2B antagonist and an opioid analgesic in accordance with the present invention, it is now possible to treat pain with a sub-maximal dose of an opioid analgesic thereby reducing the likelihood of side-effects associated with opioid analgesic usage (e.g. respiratory depression, constipation, nausea and vomiting, and tolerance and dependence and the associated problem of drug withdrawal).

A particularly preferred use for a composition of the present invention is in the treatment or prevention of post-operative pain.

Selective NMDA NR2B antagonists of use in the present invention include eliprodil (and those of EP-A-109317 and French utility certificate FR 89 04835), ifenprodil (and those of French patent FR 5733 M), Ro25-6981 (and those of EP-A-648744), compounds disclosed in WO-A-9713769 to Pharmacia and CP-101,606 (and those of EP-A-768086). A particularly favoured compound is Ro25-6981:



Particularly suitable selective NMDA NR2B antagonists can be identified by the following cascade which forms a further feature of the present invention. There is accordingly provided an assay for identifying a  
5 selective NMDA NR2B antagonist comprising:

- (i) determining a compound having an  $IC_{50}$  of less than 100 nM affinity at the human NMDA NR2B receptor and having a greater than 100-fold selectivity for NR2B receptors over human  $I_{(Kr)}$  cardiac potassium channels in radioligand binding studies;
- 10 (ii) demonstrating said compound inhibits hyperalgesia with  $ID_{50} < 30\text{mg/kg}$  i.p. or s.c. and has a greater than 10-fold window between doses producing antinociception and motor disruption in carrageenan-induced hyperalgesia in rats;
- (iii) determining said compound has an  $ID_{50}$  of less than 30mg/kg  
15 i.p. or s.c. in the rat sciatic nerve ligation assay of neuropathic pain;
- (iv) determining said compound has an  $ID_{50}$  of less than 30mg/kg p.o. in the rat carrageenan-induced hyperalgesia assays; and
- (vi) demonstrating said compound has synergistic antinociceptive effects in combination with an opioid in an assay of nociception such as  
20 inhibition of hyperalgesia induced by carrageenan or Freund's adjuvant or inhibition of allodynia in neuropathic rats.

The compounds of use in this invention may have one or more asymmetric centres and can therefore exist as enantiomers and possibly as diastereoisomers. It is to be understood that the present invention relates  
25 to the use of all such isomers and mixtures thereof.

Suitable pharmaceutically acceptable salts of the selective NMDA NR2B antagonists of use in the present invention include acid addition salts which may, for example, be formed by mixing a solution of the compound with a solution of a pharmaceutically acceptable non-toxic acid  
30 such as hydrochloric acid, fumaric acid, maleic acid, succinic acid, acetic acid, citric acid, tartaric acid, carbonic acid or phosphoric acid. Salts of



amine groups may also comprise the quaternary ammonium salts in which the amino nitrogen atom carries an alkyl, alkenyl, alkynyl or aralkyl group. Where the compound carries an acidic group, for example a carboxylic acid group, the present invention also contemplates salts thereof, preferably non-toxic pharmaceutically acceptable salts thereof, such as the sodium, potassium and calcium salts thereof.

Suitable opioid analgesics of use in the present invention include morphine, codeine, dihydrocodeine, diacetylmorphine, hydrocodone, hydromorphone, levorphanol, oxymorphone, alfentanil, buprenorphine, butorphanol, fentanyl, sufentanyl, meperidine, methadone, nalbuphine, propoxyphene and pentazocine; or a pharmaceutically acceptable salt thereof.

A particularly preferred opioid analgesic of use in the present invention is morphine; or a pharmaceutically acceptable salt thereof.

Suitable pharmaceutically acceptable salts of the opioid analgesics of use in the present invention include those salts described above in relation to the salts of selective NMDA NR2B antagonists.

Preferred salts of opioid analgesics of use in the present invention include morphine sulphate, morphine hydrochloride, morphine tartrate, codeine phosphate, codeine sulphate, dihydrocodeine bitartrate, diacetylmorphine hydrochloride, hydrocodone bitartrate, hydromorphone hydrochloride, levorphanol tartrate, oxymorphone hydrochloride, alfentanil hydrochloride, buprenorphine hydrochloride, butorphanol tartrate, fentanyl citrate, meperidine hydrochloride, methadone hydrochloride, nalbuphine hydrochloride, propoxyphene hydrochloride, propoxyphene napsylate (2-naphthalenesulphonic acid (1:1) monohydrate), and pentazocine hydrochloride.

A particularly preferred opioid analgesic of use in the present invention is morphine hydrochloride.

As stated above, the selective NMDA NR2B antagonist and opioid analgesic may be formulated in a single pharmaceutical composition or

alternatively in individual pharmaceutical compositions for simultaneous, separate or sequential use in accordance with the present invention.

Preferably the compositions according to the present invention are in unit dosage forms such as tablets, pills, capsules, powders, granules, solutions or suspensions, or suppositories, for oral, parenteral or rectal administration, or administration by inhalation or insufflation.

For preparing solid compositions such as tablets, the principal active ingredient is mixed with a pharmaceutical carrier, e.g. conventional tableting ingredients such as corn starch, lactose, sucrose, sorbitol, talc, stearic acid, magnesium stearate, dicalcium phosphate or gums, and other pharmaceutical diluents, e.g. water, to form a solid preformulation composition containing a homogeneous mixture of a compound of the present invention, or a non-toxic pharmaceutically acceptable salt thereof. When referring to these preformulation compositions as homogeneous, it is meant that the active ingredient is dispersed evenly throughout the composition so that the composition may be readily subdivided into equally effective unit dosage forms such as tablets, pills and capsules. This solid preformulation composition is then subdivided into unit dosage forms of the type described above containing from 0.1 to about 500 mg of the active ingredient of the present invention. The tablets or pills of the novel composition can be coated or otherwise compounded to provide a dosage form affording the advantage of prolonged action. For example, the tablet or pill can comprise an inner dosage and an outer dosage component, the latter being in the form of an envelope over the former. The two components can be separated by an enteric layer which serves to resist disintegration in the stomach and permits the inner component to pass intact into the duodenum or to be delayed in release. A variety of materials can be used for such enteric layers or coatings, such materials including a number of polymeric acids and mixtures of polymeric acids with such materials as shellac, cetyl alcohol and cellulose acetate.

The liquid forms in which the novel compositions of the present invention may be incorporated for administration orally or by injection include aqueous solutions, suitably flavoured syrups, aqueous or oil suspensions, and flavoured emulsions with edible oils such as cottonseed oil, sesame oil, coconut oil or peanut oil, as well as elixirs and similar pharmaceutical vehicles. Suitable dispersing or suspending agents for aqueous suspensions include synthetic and natural gums such as tragacanth, acacia, alginate, dextran, sodium carboxymethylcellulose, methylcellulose, polyvinyl-pyrrolidone or gelatin.

Preferred compositions for administration by injection include those comprising a selective NMDA NR2B antagonist, as the active ingredient, in association with a surface-active agent (or wetting agent or surfactant) or in the form of an emulsion (as a water-in-oil or oil-in-water emulsion).

Suitable surface-active agents include, in particular, non-ionic agents, such as polyoxyethylenesorbitans (e.g. Tween™ 20, 40, 60, 80 or 85) and other sorbitans (e.g. Span™ 20, 40, 60, 80 or 85). Compositions with a surface-active agent will conveniently comprise between 0.05 and 5% surface-active agent, and preferably between 0.1 and 2.5%. It will be appreciated that other ingredients may be added, for example mannitol or other pharmaceutically acceptable vehicles, if necessary.

Suitable emulsions may be prepared using commercially available fat emulsions, such as Intralipid™, Liposyn™, Infontrol™, Lipofundin™ and Lipiphysan™. The active ingredient may be either dissolved in a pre-mixed emulsion composition or alternatively it may be dissolved in an oil (e.g. soybean oil, safflower oil, cottonseed oil, sesame oil, corn oil or almond oil) and an emulsion formed upon mixing with a phospholipid (e.g. egg phospholipids, soybean phospholipids or soybean lecithin) and water. It will be appreciated that other ingredients may be added, for example glycerol or glucose, to adjust the tonicity of the emulsion. Suitable emulsions will typically contain up to 20% oil, for

example, between 5 and 20%. The fat emulsion will preferably comprise fat droplets between 0.1 and 1.0 $\mu$ m, particularly 0.1 and 0.5 $\mu$ m, and have a pH in the range of 5.5 to 8.0.

5 Particularly preferred emulsion compositions are those prepared by mixing a selective NMDA NR2B antagonist with Intralipid™ or the components thereof (soybean oil, egg phospholipids, glycerol and water).

10 Compositions for inhalation or insufflation include solutions and suspensions in pharmaceutically acceptable, aqueous or organic solvents, or mixtures thereof, and powders. The liquid or solid compositions may contain suitable pharmaceutically acceptable excipients as set out above. Preferably the compositions are administered by the oral or nasal respiratory route for local or systemic effect. Compositions in preferably sterile pharmaceutically acceptable solvents may be nebulised by use of inert gases. Nebulised solutions may be breathed directly from the  
15 nebulising device or the nebulising device may be attached to a face mask, tent or intermittent positive pressure breathing machine. Solution, suspension or powder compositions may be administered, preferably orally or nasally, from devices which deliver the formulation in an appropriate manner.

20 The present invention further provides a process for the preparation of a pharmaceutical composition comprising a selective NMDA NR2B antagonist and an opioid analgesic, which process comprises bringing a selective NMDA NR2B antagonist and an opioid analgesic into association with a pharmaceutically acceptable carrier or excipient.

25 When administered in combination, either as a single or as separate pharmaceutical composition(s), the selective NMDA NR2B antagonist and the opioid analgesic are presented in a ratio which is consistent with the manifestation of the desired effect. In particular, the ratio by weight of the selective NMDA NR2B antagonist to the opioid analgesic will suitably  
30 be approximately 1 to 1. Preferably this ratio will be between 0.001 to 1 and 1000 to 1, and especially between 0.01 to 1 and 100 to 1.

A suitable dosage level for the selective NMDA NR2B antagonist is about 0.001 to 25mg/kg per day, preferably about 0.005 to 10mg/kg per day, and especially about 0.005 to 5mg/kg per day. The compounds may be administered on a regimen of up to 6 times per day, preferably 1 to 4 times per day.

The opioid analgesic may be administered at a dosage level up to conventional dosage levels for such analgesics, but preferably at a reduced level in accordance with the present invention. Suitable dosage levels will depend upon the analgesic effect of the chosen opioid analgesic, but typically suitable levels will be about 0.001 to 25mg/kg per day, preferably 0.005 to 10mg/kg per day, and especially 0.005 to 5mg/kg per day. The compound may be administered on a regimen of up to 6 times per day, preferably 1 to 4 times per day.

It will be appreciated that the amount of a selective NMDA NR2B antagonist and opioid analgesic required for use in the treatment or prevention of pain or nociception will vary not only with the particular compounds or compositions selected but also with the route of administration, the nature of the condition being treated, and the age and condition of the patient, and will ultimately be at the discretion of the attendant physician.

The following examples illustrate pharmaceutical compositions according to the invention.

These formulations may be prepared with separate active ingredients or with a combination of active ingredients in one composition. In such combined preparations, the ratio of selective NMDA NR2B antagonist to opioid analgesic will depend upon the choice of active ingredients.

EXAMPLE 1A Tablets containing 1-25mg of compound

	<u>Amount mg</u>		
Active Ingredients(s)	1.0	2.0	25.0
Microcrystalline cellulose	20.0	20.0	20.0
5 Modified food corn starch	20.0	20.0	20.0
Lactose	58.5	57.5	34.5
Magnesium Stearate	0.5	0.5	0.5

EXAMPLE 1B Tablets containing 26-100mg of compound

	<u>Amount mg</u>		
Active Ingredients(s)	26.0	50.0	100.0
Microcrystalline cellulose	80.0	80.0	80.0
Modified food corn starch	80.0	80.0	80.0
Lactose	213.5	189.5	139.5
15 Magnesium Stearate	0.5	0.5	0.5

The active ingredient(s) cellulose, lactose and a portion of the corn starch are mixed and granulated with 10% corn starch paste. The resulting granulation is sieved, dried and blended with the remainder of the corn starch and the magnesium stearate. The resulting granulation is then compressed into tablets containing 1.0mg, 2.0mg, 25.0mg, 26.0mg, 50.0mg and 100mg of the active compound per tablet.

EXAMPLE 2 Parenteral injection

	<u>Amount</u>
Active Ingredient(s)	1 to 100mg
Citric Acid Monohydrate	0.75mg
Sodium Phosphate	4.5mg
Sodium Chloride	9mg
30 Water for injection	to 10ml

The sodium phosphate, citric acid monohydrate and sodium chloride are dissolved in a portion of the water. The active ingredient(s) is (are) dissolved or suspended in the solution and made up to volume.

5     EXAMPLE 3 Topical formulation

	<u>Amount</u>
Active Ingredient(s)	1-10g
Emulsifying Wax	30g
Liquid paraffin	20g
10     White Soft Paraffin	to 100g

The white soft paraffin is heated until molten. The liquid paraffin and emulsifying wax are incorporated and stirred until dissolved. The active ingredient(s) is (are) added and stirring continued until  
15     dispersed. The mixture is then cooled until solid.

Example 4A - (Surface-Active Agent) Injection Formulation

Active Ingredient(s)	up to 10mg/kg
20     Tween 80™	up to 2.5%
[in 5% aqueous mannitol (isotonic)]	

The active ingredient(s) is (are) dissolved directly in a solution of the commercially available Tween 80™ (polyoxyethylenesorbitan  
25     monooleate) and 5% aqueous mannitol (isotonic).

Example 4B - (Emulsion) Injection Formulation

Active Ingredient(s)	up to 30mg/ml
30     Intralipid™ (10-20%)	

The active ingredient(s) is (are) dissolved directly in the commercially available Intralipid™ (10 or 20%) to form an emulsion.

Example 4C - Alternative (Emulsion) Injectable Formulation

5		<u>Amount</u>
	Active Ingredient(s)	0.1 - 10mg
	Soybean oil	100mg
	Egg Phospholipid	6mg
	Glycerol	22mg
10	Water for injection	to 1ml

All materials are sterilized and pyrogen free. The active ingredient(s) is (are) dissolved in soybean oil. An emulsion is then formed by mixing this solution with the egg phospholipid, glycerol and water. The emulsion is then sealed in sterile vials.

The following Example illustrates that selective NMDA NR2B receptor antagonists have a reduced motor side-effect profile when compared with NMDA/glycine antagonists.

EXAMPLE 5

The present Example examined whether NMDA NR2B receptor antagonists have an improved therapeutic window over unselective NMDA/glycine antagonists and other ion channel blockers including lamotrigine and gabapentin, by comparing their anti-algesic effects with their liability to induce motor impairment in rats. Anti-algesic activity was assessed using an assay of neuropathic pain in rats (sciatic nerve ligation) and in a carrageenan-induced hyperalgesia assay. Motor impairment was measured using an accelerating rotarod.



## Methods

For sciatic nerve ligation, male Sprague Dawley rats (180-220g) were anaesthetised with isofluorane, the left sciatic nerve exposed and 4 chromic catgut (4.0) ligatures were tied loosely around the nerve (spaced 1-5 2 mm apart) immediately proximal to the point of trifurcation. In sham-operated animals, the same dissection was performed but without ligation. Responses to mechanical pressure were assessed 7 days after ligation using a modified Randall-Selitto algometer in which constant force of 40 mmHg was applied to the hind paw and the latency to struggle was 10 recorded as the reaction time. Mechanical allodynia was defined as the difference in reaction time for sham and ligature rats. Reaction times for drug treated rats were expressed as a percentage of this response. Compounds were administered 1 h before the test.

In the carrageenan-induced hyperalgesia assay, male Sprague Dawley rats 15 (100-120 g) received an intraplantar injection of carrageenan (4.5 mg) and mechanical thresholds were determined 3 h later using a modified Ugo Basile Algometer. Control rats received saline (0.15 ml i.pl.). Hyperalgesia was defined as the difference in vocalisation threshold for saline- and carrageenan-injected rats. Paw pressure scores for drug- 20 treated rats were expressed as a percentage of this response. Compounds were administered 2 h after carrageenan.

To determine the effects of the compounds on motor co-ordination, male Sprague Dawley rats (160-180 g) were first trained to remain for 120 s on the rotarod apparatus revolving at 12 r.p.m. on the morning before the 25 test. Animals then received drug treatments and 1 h later were placed on an accelerating rotarod (increasing from 4 - 40 r.p.m. during a 5 min period) and the time the rats were able to remain on the rotarod recorded. Lamotrigine, gabapentin and ( $\pm$ )-CP-101,606 were suspended in 0.5% methocel and administered orally (1 ml/kg). Ifenprodil, L-701,324, L- 30 687,414 and ( $\pm$ )-Ro25-6981 were dissolved or suspended in 0.5% methocel and administered intraperitoneally (1 ml/kg). MK-801 was

dissolved in distilled water and given i.p. (1 ml/kg). Doses of compounds refer to the free base.

## Results

### 5 *Anti-algesia studies*

Animals with sciatic nerve ligation exhibited mechanical allodynia as measured by the reduction in the reaction time to withdraw the injured limb from the paw pressure apparatus. Reaction times for sham and ligature rats were typically  $22 \pm 1$  s and  $8 \pm 1$  s, respectively. The NMDA NR2B antagonists, ( $\pm$ )-CP-101,606 and ( $\pm$ )-Ro25-6981, the NMDA/glycine receptor antagonist L-701,324 and partial agonist L-687,414 and the non-competitive NMDA antagonist MK-801 dose-dependently reversed mechanical allodynia induced by sciatic nerve ligation (Table 1). Similarly, the novel anti-convulsant drugs, lamotrigine and gabapentin, and the vasodilator ifenprodil, which has affinity for the NMDA NR2B receptor, reversed mechanical allodynia. The order of potency was: MK-801 > L-701,324 > ( $\pm$ )-Ro25-6981 > ( $\pm$ )-CP-101,606 > ifenprodil > L-687,414 > lamotrigine > gabapentin.

Intraplantar injection of carrageenan (4.5 mg) induced marked paw oedema and hyperalgesia to mechanical compression of the inflamed hind paw. All the compounds caused a dose-dependent inhibition of mechanical hyperalgesia induced by carrageenan (Table 1). The order of potency was: MK-801 > L-701,324 > ( $\pm$ )-Ro25-6981 > ifenprodil > ( $\pm$ )-CP-101,606 > L-687,414 = gabapentin > lamotrigine.

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### *Effects on behaviour and motor co-ordination*

Vehicle-treated rats were able to remain on the accelerating rotarod for approximately 140 s. MK-801 dose-dependently induced impairments in rotarod performance with an  $ID_{50}$  of 0.22 mg/kg i.p. Body rolling, and head weaving were also observed following 0.3 and 1 mg/kg doses of MK-801. The NMDA/glycine receptor antagonist L-701,324 and partial agonist

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L-687,414 also induced rotarod deficits ( $ID_{50}$  of 1.9 mg/kg i.p. and 53.3 mg/kg i.p.); ataxia was evident at 10 and 30 mg/kg i.p. of L-701,324 and L-687,414 induced body rolling and ataxia at 100 and 300 mg/kg i.p.

Ifenprodil caused approximately 50% impairment in rotarod performance at 50 mg/kg, however, severe adverse effects were also observed at this dose (ptosis, piloerection, hypoactivity and hyperventilation). Gabapentin caused motor impairments (ataxia) at doses of 30-300 mg/kg ( $ID_{50}$  for rotarod was 133 mg/kg i.p.). Administration of lamotrigine at 500 mg/kg p.o. caused a 40% inhibition in the time spent on the rotarod; no other effects were observed at this dose. Similarly, ( $\pm$ )-Ro25-6981 induced a 47% inhibition of rotarod performance at a dose of 100 mg/kg i.p. ( $\pm$ )-CP-101,606 did not inhibit motor performance on the rotarod up to 300 mg/kg p.o.; in fact, there was a significant increase in latency following 300 mg/kg dose compared to vehicle-treated rats.

The ratios for the  $ID_{50}$  inducing motor impairment and inhibition of allodynia in neuropathic rats were at least 4 fold greater for the NMDA NR2B receptor antagonists, ( $\pm$ )-CP-101,606 (ratio >49) and ( $\pm$ )-Ro25-6981 (ratio  $\geq 26$ ), than were found for MK-801 (ratio 1.1), the NMDA/glycine antagonists (ratio <6), gabapentin (ratio 1.5) and ifenprodil (ratio 5.3). Lamotrigine had a similar profile to that of the NMDA NR2B receptor antagonists (ratio >45).

## Conclusions

These data suggest that NMDA NR2B antagonists may be useful for treating neuropathic pain in man with an improved therapeutic window over clinically used unselective ion channel blockers.

Table 1. Summary of the anti-algescic and ataxic properties of NMDA receptor antagonists and other ion channel blockers

	ID <sub>50</sub> (mg/kg)				Ratio
	Antinociception		Motor Impairment		
	Rat Ligation	Rat Carrageenan	Rat Rotarod	Rotarod/ Rat Ligation	
Lamotrigine (p.o.)	11	207	>500	>45	
Gabapentin (p.o.)	87	50	133	1.5	
Ifenprodil (i.p.)	9.5	17	>50	5.3	
MK-801 (i.p.)	0.19	0.21	0.22	1.1	
L-701,324 (i.p.)	2.6	2.5	1.9	0.7	
L-687,414 (i.p.)	9.8	50	53	5.4	
(±)-CP-101,606 (p.o.)	6.1	37	>300	>49	
(±)-Ro25-6981 (i.p.)	3.8	5.7	>100	>26	

The following Example demonstrates the synergistic antinociceptive effects of a combined treatment of the selective NMDA NR2B antagonist (±)-Ro25-6981 with morphine.

5           EXAMPLE 6

The present Example examined whether the NMDA NR2B antagonist (±)-Ro25-6981 could potentiate the antinociceptive effects of morphine in an assay of inflammatory hyperalgesia in rats to determine  
10 whether such combination therapies may provide improved analgesic efficacy with reduced side-effects in man.

**Methods**

Male Sprague Dawley rats (100-120 g) received an intraplantar  
15 injection of carrageenan (4.5 mg) and mechanical thresholds were determined 3 h later using a modified Ugo Basile Algesiometer. Control rats received saline (0.15 ml i.pl.). Hyperalgesia was defined as the difference in vocalisation threshold for saline- and carrageenan-injected rats. Paw pressure scores for drug-treated rats were expressed as a  
20 percentage of this response. Compounds were administered 2 h after carrageenan.

To determine the effects of morphine and (±)-Ro25-6981 on motor coordination, male Sprague Dawley rats (160-180 g) were first trained to remain for 120 s on the rotarod apparatus revolving at 12 r.p.m. on the  
25 morning before the test. Animals then received drug treatments and 1 h later were placed on an accelerating rotarod (increasing from 4 - 40 r.p.m. during a 5 min period) and the time the rats were able to remain on the rotarod recorded.

(±)-Ro25-6981 was suspended in 0.5% methocel and administered intraperitoneally (1 ml/kg). Morphine HCl was dissolved in saline and given subcutaneously (1 ml/kg). Doses of compounds refer to the free base.

## 5 Results

### *Effect of Ro25-6981 on Carrageenan-Induced Hyperalgesia*

Intraplantar injection of carrageenan (4.5 mg) induced marked paw oedema and hyperalgesia to mechanical compression of the inflamed hind paw. Intraperitoneal (i.p.) administration (±)-Ro25-6981 caused a dose-  
10 dependent reversal of mechanical hyperalgesia induced by carrageenan at doses of 10 and 30 mg/kg (Figure 1). A dose of 1 mg/kg was chosen for combination experiments as this did not cause significant antinociception.

### 15 *Combination of Ro25-6981 and Morphine on Carrageenan-Induced Hyperalgesia*

Subcutaneous (s.c.) administration of morphine alone at 1 mg/kg completely reversed mechanical hyperalgesia induced by carrageenan whereas lower doses of 0.1 and 0.3 mg/kg were without effect (Figure 2). Combined administration of a subthreshold dose of (±)-Ro25-6981 (1 mg/kg  
20 i.p.) with a subthreshold doses of morphine (0.1 and 0.3 mg/kg) resulted in a significantly greater inhibition of hyperalgesia (Figure 2). The percent inhibition following a dose of 0.1 mg/kg of morphine was increased from 11% to 80% and following a dose of 0.3 mg/kg from 31% to 94%.

### 25 *Combination of Ro25-6981 with Morphine on Rotarod Performance*

Treatment with (±)-Ro25-6981 (1 mg/kg i.p.) alone had no effect on rotarod performance (Figure 3). Treatment with morphine alone at 3 mg/kg s.c. induced a significant impairment in rotarod performance whereas lower doses of 0.3 and 1 mg/kg had no effect (Figure 3). Similarly,  
30 when combined with (±)-Ro25-6981 (1 mg/kg i.p.), the minimum effective dose of morphine causing rotarod disruption was 3 mg/kg (Figure 3).

### Conclusions

These data demonstrate that administration of ( $\pm$ )-Ro25-6981, at a dose that is ineffective by itself, can markedly potentiate the antinociceptive effects of morphine. In contrast, there was no significant interaction between ( $\pm$ )-Ro25-6981 (1 mg/kg) and morphine (0.3-3 mg/kg) on the rotarod indicating that motor impairment induced by morphine is not potentiated by ( $\pm$ )-Ro25-6981.

**CLAIMS**

1. A product comprising a selective NMDA NR2B antagonist and an opioid analgesic as a combined preparation for simultaneous,  
5 separate or sequential use in the treatment of pain or nociception.
2. A product according to claim 1 wherein the NR2B antagonist is eliprodil or ifenprodil.
- 10 3. A product according to claim 1 or 2 wherein the opioid analgesic is morphine, codeine, dihydrocodeine, diacetylmorphine, hydrocodone, hydromorphone, levorphanol, oxymorphone, alfentanil, buprenorphine, butorphanol, fentanyl, sufentanyl, meperidine, methadone, nalbuphine, propoxyphene and pentazocine; or a  
15 pharmaceutically acceptable salt thereof.
4. A production according to claim 3 wherein the opioid analgesic is morphine or a pharmaceutically acceptable salt thereof.
- 20 5. A pharmaceutical composition comprising a selective NMDA NR2B antagonist and an opioid analgesic together with at least one pharmaceutically acceptable carrier or excipient.
6. The use of a selective NMDA NR2B antagonist and an opioid  
25 analgesic for the manufacture of a medicament for the treatment of pain or nociception
7. A method for the treatment or prevention of pain or  
30 nociception, which method comprises administration to a patient in need of such treatment of an amount of a selective NMDA NR2B antagonist and

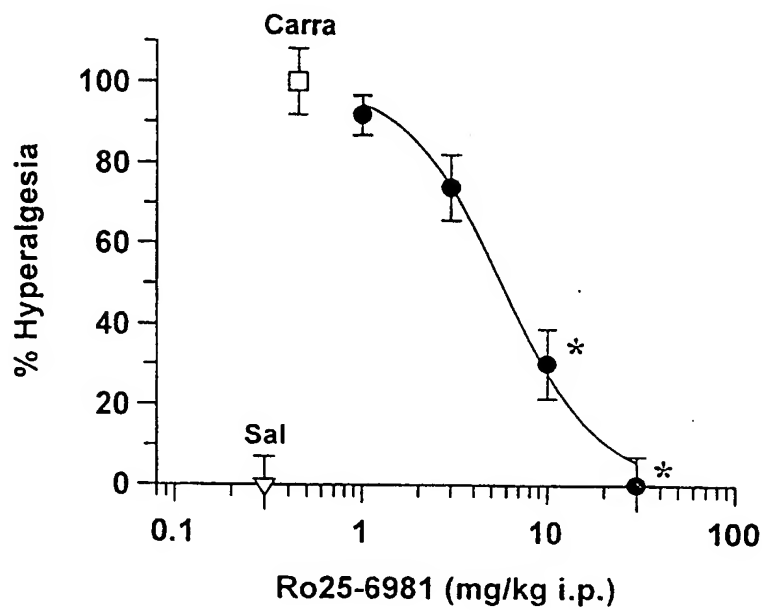


an amount of an opioid analgesic such that together they give effective pain relief.

- 5           8.     A process for the preparation of a pharmaceutical composition comprising a selective NMDA NR2B antagonist and an opioid analgesic, which process comprises bringing a selective NMDA NR2B antagonist and an opioid analgesic into association with a pharmaceutically acceptable carrier or excipient.

Figure 1

Inhibition of carrageenan-induced mechanical hyperalgesia by the NMDA NR2B antagonist R025-6981 in rats

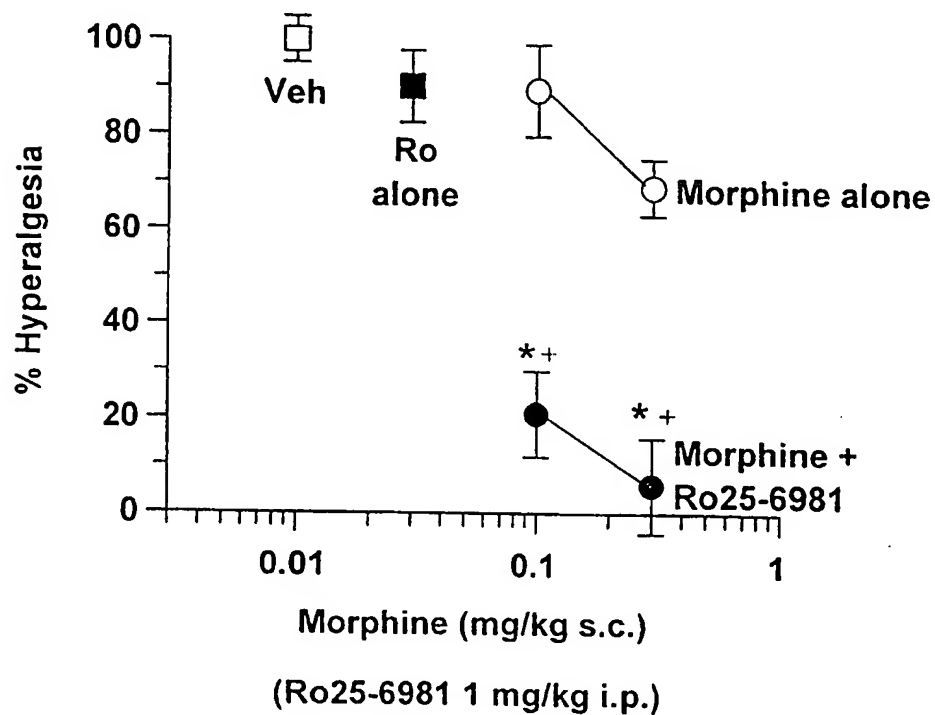


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\*p<0.05 compared to Carrageenan/vehicle

Figure 2

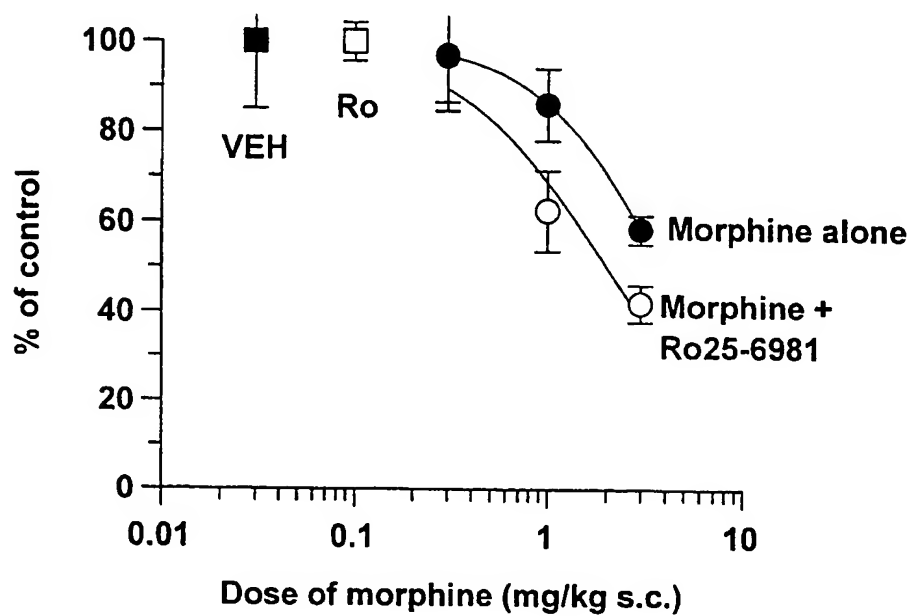
Effect of combination of morphine with the NMDA NR2B antagonist Ro25-6981 on carrageenan-induced hyperalgesia



\*  $p < 0.05$  compared to vehicle treated

+  $p < 0.05$  compared to morphine alone

**Figure 3**  
**Effect of morphine alone and in combination with the NMDA NR2B antagonist Ro25-6981 on motor co-ordination on the accelerating rotorod**



# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/00585

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 A61K31/485 //(A61K31/485,31:445)

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PRICE D D ET AL: "EFFECTS OF THE COMBINED ORAL ADMINISTRATION OF NSAIDS AND DEXTROMETHORPHAN ON BEHAVIORAL SYMPTOMS INDICATIVE OF ARTHRITIC PAIN IN RATS" PAIN, vol. 68, no. 1, 1 November 1996 (1996-11-01), pages 119-127, XP002061724 page 126, column 1, paragraph 2	1-8
A	HILL R.: "8th World Pain Congress" EXPERT OPINION ON INVESTIGATIONAL DRUGS (EXPERT OPIN. INVEST. DRUGS), 5/11 (1549-1562), XP002110414 United Kingdom page 1556, column 1, paragraph 5	1-8
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

27 July 1999

Date of mailing of the international search report

10/08/1999

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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/00585

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>US 5 668 121 A (LI JAMES JIA-HE ET AL)  16 September 1997 (1997-09-16)  column 3, line 53 - line 55  -----</p>	1-8

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/GB 99/ 00585

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:  
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims: it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

## Continuation of Box I.2

Present claims relate to an extremely large number of possible combinations. Support within the meaning of Article 6 PCT and/or disclosure within the meaning of Article 5 PCT is to be found, however, for only a very small proportion of the compositions claimed. In the present case, the claims so lack support, and the application so lacks disclosure, that a meaningful search over the whole of the claimed scope is impossible. Consequently, the search has been carried out for those parts of the claims which appear to be supported and disclosed, namely those parts relating to the combination of active ingredients mentioned in example 6 of the description.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.



# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 99/00585

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5668121 A	16-09-1997	US 5489717 A	06-02-1996